E/CONF.39/A/119
16 Oct.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.4.1.2

Economic Commission
for Europe

EVALUATION OF FORESEEABLE ENERGY REQUIREMENTS

By The Energy Division
of the Economic Commission for Europe

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

2. Papers selected for inclusion in Specialized Sessions will be available at the Conference in only one of the above official languages.

3. Summaries of all papers, as submitted by contributors, will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

4. Papers and summaries will not be available for general distribution in advance of the Conference. They will be published in advance in limited quantities only for the use of delegations of participating governments and of other authorized participants. Post-Conference publication and general distribution of the Conference Proceedings will follow United Nations practices as laid down by the United Nations Publications Board.

EVALUATION OF FORESEEABLE ENERGY REQUIREMENTS

by

The Energy Division of the Economic Commission For Europe

I. Introduction

1. The difficulties which confront newly developing countries in evaluating their needs for inanimate energy are clearly greater in general than those - already fraught with hazard where the energy economy as a whole is concerned - which face countries already highly industrialized. These difficulties are of various kinds. They commonly stem from a lack of reliable time series - both for basic economic indices and for data on different types of energy use by the main categories of consumers. Moreover, relationships between sets of data which should yield slowly evolving "elasticity coefficients" are likely to be irregular. Magnitudes involved are small, so that new installations also impart a step-like character to the growth trends. Consumption tends to be limited by production possibilities. Thus the building, say, of a sizeable hydro-electric plant may attract to the region concerned a body of consumers which soon assumes a "snowball" character, so that the regional estimate of requirements quickly becomes obsolete. Prices paid for such commercial forms of energy as are available are usually high and serve to distort the latent pattern of demand which eventually must emerge. Short-term allocation of capital expenditure between different priorities may have a similar effect. Finally, the development trends in different regions of the country may be largely unrelated to one another, in part because of the lack of any nationally integrated energy supply system.

2. The main problems which face more developed countries are either those which arise from fluctuations in economic activity, and possibly from changes in interest rates and purchasing power imposed by government fiscal policy: or those which underlie the substitution of one form of energy for another - differences in rates of technical progress in different fields; in availability and relative cost of different sources of energy outside the country; and sometimes the effects of new discoveries or the using-up of indigenous energy reserves. It is often difficult to distinguish the one basic source of variation from the other. Inadequacy of statistical data remains a problem to some extent - for example, in respect of the socio-economic characteristics of retail consumers.

3. In essence many of the problems of assessing energy requirements in highly developed countries are shared by or are at least incipient in those where development is at an earlier stage, much of the difference in practice being due to the greater stability and comparability of trends in time series in the former group owing to much higher, more diversified and more evenly distributed levels of consumption per head. Factors responsible for these differences in the basic situation must generally be expected to diminish, rather than to increase, in the future. Some forms of analysis available in highly developed countries - Leontief input-output

matrices, for example - cannot be applied at all in those at a much earlier stage. Nevertheless, lessons which have been learned comparatively recently in the former group under conditions existing during the post-war period may usually be instructive for the latter, and may allow them to build on somewhat surer foundations.

4. It is sometimes stated that while all countries have energy requirements not all possess natural energy reserves, so that in newly developing countries requirements should be taken as the point of departure. On a long-term view this idea is contradicted by experience, particularly in Europe, where nearly all countries may be arranged in a series varying from those possessing (or using) an abundance of coal and little or no hydro power to those where hydro-electric resources are very great but are virtually (apart from fuel wood) the sole internal source of energy. The structure of the energy supply, the relative importance of electricity and of industries which require large quantities of kWh at low cost, the use of electric energy in the home and for other low-voltage uses - these are broadly correlated with this basic pattern of natural resources. Differences which remain are largely due to geographical position affecting fuel imports and general trade; the presence or absence of other non-energy resources; and, of course, the level of total national product per inhabitant already reached. This last is important because recent research seems to show that the evolution of energy requirements in response to economic development involves a distinctive development process, in which primary energy needs, and in particular the role of electricity therein, grow at rates which do not remain simply proportionate to industrial production or even to total national product.(1)

5. Methods of evaluating future energy requirements differ according to the source of energy concerned. They must therefore be considered so far as possible, in relation to the foreseeable pattern of internal commercial energy reserves (future changes in use of non-commercial sources must be allowed for also) and to the expected composition and source of the energy supply as a whole. With this in mind it will be worth while to review first the essentials of the different methods of planning and forecasting available where sophisticated methods are at least possible and then to consider how far these are relevant to countries at earlier stages of development.

II. Methods of evaluating future requirements

6. If we consider this problem as one of satisfying a country's energy needs as economically as possible, then methods of forecasting form only one group of a series of related analytical and planning procedures which must eventually be considered in conjunction with one another. At this point it is the methods of projecting future requirements, mainly for medium-term estimating for, say, 5, 10 or 15 years ahead, that are taken into account.

7. Methods of arriving at future energy needs in an economy where production of goods and services is rising may be reduced to the following:

- direct extrapolation of rates of change in requirements based on analysis of past experience;
- extrapolation from functional relationships between two or more variables, one of which is that to be forecast;
- extrapolation of requirements per unit of product applied to planned or expected production;
- evaluation of a development trend from comparative study of its homologues in different countries.

8. In practice these methods may well be used as alternatives to check one another. In such a case it is common for one or more methods to be applied to deduce future requirements by different main consumer-groups, and possibly also in different regions, and then to bring together the results. One or more alternative methods would then be applied on an overall basis to see how far the results conform to the expected development of the economy as a whole.

9. Different forms of energy show widely different rates of growth in requirements. Some are also far more sensitive than others to fluctuations in economic activity (2) and also more vulnerable to competition from other energy sources. The range of methods available for use thus varies from one form to another, and it is common practice to estimate needs for forms of energy which are residual or the least competitive by difference, after defining requirements for those types of use which are the more dynamic. There is thus an order of forecasting to be considered if all main forms of energy are to be taken into account in a co-ordinated series of projections. In practice, however, the emphasis in most energy projections is placed on electric power needs, which nearly everywhere have for long been growing at a high exponential rate. and playing an ever-greater role in the total energy supply. In a number of countries coal requirements, other than those for coking or for use in power plants, tend to fall at the opposite extreme.

(a) Direct extrapolation of rates of change

10. In practice this procedure is very widespread and must often be used in less developed countries. Various methods may be used to arrive at an average rate of change per unit period from the historical data after these have been corrected for such influences as normal seasonal variation, the effects of abnormal stoppages (3), and in suitable cases for the effects of departures from normal conditions during the winter heating season (4). Some ways of deriving a selected exponential rate (i.e. one which projects as a straight line on a semi-logarithmic scale) from a short time series are outlined in reference (5). It is, however, good practice also to use a matrix Table for this purpose, each year in the series being listed in order both vertically and horizontally. The average percentage rate for every combination of periods is then inserted in the appropriate cell. In this way it is possible to see at once how far rates for different periods have varied and to select that which is considered most significant for projection purposes.

11. Another method of extrapolation is sometimes used involving exponentially weighted moving averages. This consists in selecting the chosen value in such a way as to give more weight to the most recent rates experienced (6). It is possible to derive formulae of this type which at the same time allow for seasonal fluctuations in the data.

12. Projections based on empirically determined degressive formulae (7), or on expressions giving a modified exponential curve, a logistic or "S" curve or a Gompertz curve determined from analysis of past time series (8), all fall within the category of direct extrapolation from past trends. In most cases these methods are over-ambitious in the circumstances discussed here. It is, however, possible that the acceleration reflected in the lower portion of a logistic trend may have some importance. This question is referred to below in connexion with comparative international studies.

(b) Extrapolation from functional relationships

13. This method may be used in a complex way, involving the working out of many relationships for different sectors of the economy so as to arrive at an overall econometric "model" which must be revised periodically; or it may imply a use of

simple relationships found between energy requirements and such overall economic indicators as are available. In the latter case simple or multiple regression equations expressing linear or non-linear relationships may be used; but in the present context the simple "elasticity coefficient" obtained by dividing one index of change by another (the two indices being referred to the same base year) may often be the more suitable. In suitable circumstances the relationships expressed by such coefficients evolve more regularly and change more slowly than do the actual data themselves. To give a very general example, while an index for total national product divided into one for total energy input expressed in kcal may at an early stage of economic development give a coefficient equal to or above unity, the gradual rise in average efficiency of energy use is likely to reduce it to a value of around 0.8 at a much later stage.

14. In the case of electric power at least (the analogy may perhaps be extended) it is instructive to consider rising annual requirements in kWh as the product of three main components - connexions of new consumers; the level of economic activity; and an electrification factor which reflects the extension of power to new uses. If C represents consumption and I is an industrial production index, the following expression is not untypical for some well-electrified countries:

$$\frac{C_1}{C_o} = \frac{I_1}{I_o}^{0.4} \times 1.05$$

Here practically all existing consumers are connected up and the factor for application to new uses is taken as 5 per cent.

15. This type of approach may be useful in less-developed countries only as a model for the use of judgment in estimating rather than as a statistical exercise. A formula of similar type has however been derived for the world on the basis of experience since 1937 (9). (see also Figure 1).

(c) Extrapolation based on the product of planned levels of activity and specific energy needs per unit

16. This method is sometimes employed very simply, as for example by applying to a population projection an extrapolation of average consumption per inhabitant. It is, however, also applied in great detail, using the planned output of each industrial sector, transport in ton/km etc., and projecting expected consumption per unit of product to obtain aggregate requirements for each different form of energy. This is the basic method used in preparing the economic plans of centrally-directed economies. In such cases method (b) above is commonly used as a check where long-term perspective plans are undertaken.

(d) Evaluation of development trends from comparison of tendencies in different countries

17. Comparison between trends in different countries can be based on the idea of direct extrapolation (method (a) above) or on that of extrapolation of relationships (method (b)). Where a particular energy category exhibits a more or less consistent type of growth in many different countries over a long period it is possible to compare:

- long-term changes in growth rates for single countries;
- short-term growth rates in different countries at the same time;
- growth tendencies in countries at widely different levels of specific consumption.

18. There is probably more scope for extending the use of this method than has so far been realized. When method (b) above is employed to study, for example, parallel developments in indices of economic activity, total calorific input of energy and electric power consumption for countries at different stages, the main lines of the likely evolution of energy requirements tend to emerge more clearly. The logistic or "S" curve development which characterizes so many economic and social trends can also be studied in its earlier stages where electric power is concerned, although the point of inflexion and the ensuing development stages cannot yet be established with any precision. This is in part because the trend of total consumption is compounded of a number of separate logistic surges, which can still arise in some fields of use.

19. For countries at the earlier stages of development this method of international comparison can be partially taken into account by comparing developments in demand elsewhere under more or less homologous conditions. While for instance annual rates of increase in a country's electric power requirements often tend at the outset to be rather low (around 5 per cent) they quite commonly appear to accelerate rapidly (to some 15 per cent or more) at around 100 kWh per head before declining somewhat at considerably higher levels of specific consumption (10).

III. Consolidation of energy projections

20. In most industrialized countries electric power requirements tend to be taken as the point of departure when consolidated energy projections are attempted. In recent experience future electric power demands have usually been under-estimated. This applies to total consumption and to forecasts of the maximum annual load to be met. In general it is found that continuing rapid growth nearly everywhere makes the consequences of under-estimating more serious than those which would be likely to follow from moderate optimism. The only proviso here for less-developed areas is that concentration on a large power project in a particular locality - say, an important hydro-electric scheme - without taking sufficient account of its effect on neighbouring localities (for example through their irrigation needs) and without ensuring either adequate transmission facilities or else immediate local demand expectations can, and sometimes does, mean that scarce capital will not be used initially to the best advantage.

21. Projection of electric power requirements tends to allow the greatest scope for sophistication so far as method is concerned. For less-developed areas it is likely to be sufficient to employ as many of the above-mentioned forecasting procedures as the available data allow in their simplest form, and making all possible allowance for personal judgement. It will usually be desirable to attempt to define requirements for each region separately and to compare their aggregate with a relatively simple national forecast to see how far conditions resemble those which may exist elsewhere. Where other energy needs are to be evaluated at the same time it has usually been found best to proceed by elimination, using whichever of the above methods of projection is best adapted to the conditions and trends of demand and supply for each form of energy, after taking the following criteria into account:

- degree of specificity of supply sector and freedom from substitution;
- constancy of trend and actual rate of change;
- closeness of correlation with other economic series;
- availability of data for the past;
- extent to which supplies depend on production possibilities;
- extent to which requirements can be estimated by difference.

22. Unlike forecasts required for plant construction programmes, comprehensive energy projections for general guidance can usefully be made as simply as possible and revised at frequent and regular intervals. Even in highly industrialized countries comparatively simple projection methods must often be used for some energy categories. Combining of the different estimates may then be a matter of reconciling alternatives based on different assumptions, for example as to future price ratios per calory for some competitive uses of coal and liquid fuels. Alternative estimates of growth in total national product and industrial output at least may have to be employed also.

IV. Study of requirements in relation to evaluation of natural resources and total system planning

23. It is difficult to overestimate the importance of making surveys of water resources and natural fuel reserves in a comprehensive manner at the earliest possible stage (11). The same remark applies to other natural resources of energy-consuming importance. Rapid preliminary assessments will be inaccurate in various respects. If they employ common methods throughout the entire country they will nevertheless serve to throw light on three important questions: the probable future composition of the energy supply; the likely distribution of economic activity and of local energy needs; and the probable future requirements for transmission and transport facilities in order to distribute supplies economically and take advantage of local diversity in plant and needs so as to increase the utilization of equipment that can be interconnected.

24. No mention is made here of a number of associated questions of major importance. Even the analysis of the existing energy economy from the stage of primary energy input to that of end-use consumption poses many problems not discussed. The order of priority to be accorded to different productive projects is also a complex question not easily resolved even in economically advanced countries. Because in newly developing areas the coming of supplies of electric power and other forms of energy can exert such a strong influence on demand, the aspect of evaluating, siting and linking-up the potential productive facilities may well merit as much attention at the outset as the analysis of the energy requirements themselves.

LIST OF BIBLIOGRAPHICAL REFERENCES

(Noted in the text)

1. The Situation and Prospects of Europe's Electric Power Supply Industry in 1959/60. Doc. ST/ECE/EP/9, United Nations, Geneva, (1961). (especially Chapter II).

2. Chandler, G. & Priddle R.: The Influence of Economic Fluctuations on the Demand for Energy. World Power Conference, Madrid (1960).

3. Etudes Economiques présentées par le Comité de Direction. Congress of UNIPEDE (International Union of Producers and Distributors of Electric Power), London (1955).

4. The Situation and Future Prospects of Europe's Electric Power Supply Industry in 1961/62. United Nations, Geneva. (to be issued early in 1963).

5. H. Beard & A. Pedder: Forecasting Electricity Requirements. World Power Conference, Madrid (1960).

6. A. Merrett & G. Bannock: Business Economics and Statistics (Chapter 5). Hutchinson, London (1962).

7. Robinson, E.A.G. & Daniel G.H.: The World's Need for a New Source of Energy. Proceedings of the International Conference on the Peaceful Uses of Atomic Energy 1955. Vol. I, United Nations, New York (1956).

8. F. Mills: Statistical Methods (Appendix F). Henry Holt & Co., New York (1955).

9. de Felice, J. & Tiberghien, E: Rapport Général sur le Niveau d'Emploi de l'énergie électrique dans l'Industrie. Congress of UNIPEDE, London (September 1955).

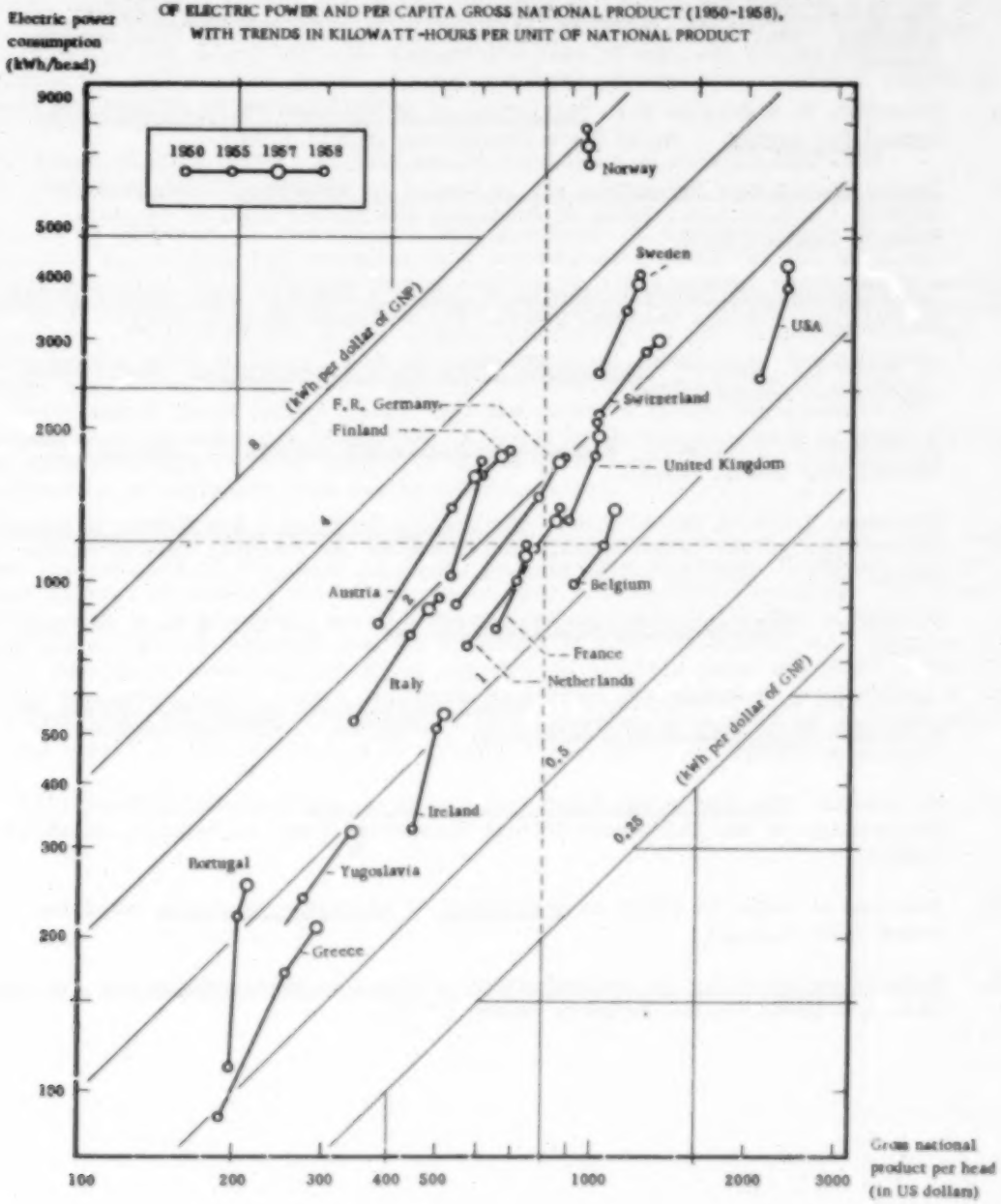
10. A. Grauer: The Electrical Power Industry in Canada (especially Chart II); Proceedings of the Thirteenth British Electrical Power Convention, Eastbourne. (1961).

11. See also a companion paper on evaluation of hydraulic resources submitted under Point A.3.1.1.

12. Methods employed for the determination of electric power consumption forecasts. Doc. E/ECE/224, United Nations, Geneva (1956).

Figure 1

RELATIONSHIPS IN SELECTED COUNTRIES BETWEEN PER CAPITA GROSS CONSUMPTION OF ELECTRIC POWER AND PER CAPITA GROSS NATIONAL PRODUCT (1950-1958), WITH TRENDS IN KILOWATT-HOURS PER UNIT OF NATIONAL PRODUCT



NOTE: Gross national product is expressed in US dollars per inhabitant at constant (1954) prices.